

## Claims

### Claim 1

#### I Claim:

A method for improving accuracy in an implement for measurement or control of a physical quantity by canceling out error due to an interfering noise  $N$  so as to provide an error corrected output  $V_c$ , sensitive to a signal input  $I$ , which includes the steps:

find or construct a sensor with an output  $V$  which has a signal to noise ratio SNR which changes substantially when the condition of an operating parameter  $Q$  is selectively modulated,

provide means whereby said output  $V$  of the said sensor in a higher said SNR state due to a condition of said operating parameter  $Q$  is combined with said output  $V$  of said sensor in a lower said SNR state due to a different said condition of said operating parameter  $Q$ , and

adjust said combined so that the said noise  $N$  mostly cancels but said sensor continues to have a good gain for said signal input  $I$ .

### Claim 2

A method as claimed in claim 1, wherein said input  $I$  and said noise  $N$  are conditioned, or generally change by only a small amount during the time duration of one full operating cycle of change of said condition of said operating parameter  $Q$ .

### Claim 3

A method as claimed in claim 1, wherein said sensor comprises at least two said sensors or a composite sensor having at least two sectors, and wherein each one of said two sensors or said two sectors operates full time at a different said condition of said operating parameter  $Q$ ,

so that there is thereby no need to have a short operating cycle time and no need to condition said input I and said noise N or require that they be generally constant over said one full operating cycle.

Claim 4

A method as claimed in Claim 1 wherein said sensor is a non-contact ammeter which incorporates at least one Hall device associated with a magnetic core SQ.

Claim 5

A method as claimed in Claim 1 wherein said sensor is a non-contact ammeter which incorporates at least one Hall device associated with a magnetic core SQ, and

wherein said operating parameter Q is the magnetic reluctance of said magnetic core SQ.

Claim 6

A method as claimed in claim 1 wherein said sensor is a non-contact ammeter which incorporates a Swain type sense coupling winding  $N_s$  wound on a core SQ.

Claim 7

A method as claimed in claim 1 wherein said sensor is a non-contact ammeter which incorporates a Swain type sense coupling winding  $N_s$  on a core SQ, and wherein said operating parameter Q is the peak current  $I_{sm}$  in said sense coupling winding  $N_s$ .

Claim 8

An implement with a sensor for measurement or control having an output V which changes when a desired signal input called I, changes,

and also wherein said output V of said sensor changes so that it has an error when an interfering noise source called N changes,

said signal I and said noise N required to be inherently or conditioned to be largely constant in magnitude and direction for a time duration here called  $T_{A+B}$ ,

and means are provided to largely correct said error while preserving said input at an output of said implement here called  $V_c$ , and

said sensor is further chosen or constructed so that it has the essential characteristic that when the condition of an operating parameter Q is changed by a selective modulator, the sensitivity of said output V to said signal I is altered substantially differently from the sensitivity of said output V to said noise N in a manner called selective modulation;

more particularly, in said sensor said output V change per unit signal input I change is here called gain g, i.e.,

$$g \equiv \frac{\delta V}{\delta I}, \text{ and}$$

said output change per unit noise change is here called noise sensitivity  $\Psi$ ,

defined as the change in said output per unit change in said noise, all divided by said gain, i.e.,

$$\Psi \equiv \frac{\delta V / \delta N}{g}, \text{ and}$$

said operating parameter Q has at least two conditions here called  $M_A$  and  $M_B$  which are provided by means enabling, and

a timing means is provided with at least two states (A) and (B) having a total cycle time equal to or less than said  $T_{A+B}$ , and arranged to coordinate the action of said modulator,

means are provided whereby said output V is available as output  $V_A$  when in said condition  $M_A$  in said state (A) and also said output is available as output  $V_B$  when in said condition  $M_B$  in said state (B),

means are provided for combining said output  $V_A$  and said output  $V_B$  so that said noise  $N$  is largely canceled at said implement output  $V_C$ , and good gain  $g$  remains so that said implement output  $V_C$  is well responsive to said input  $I$ ,

said means for combining constructed to accomplish much the same result as the following example:

means are provided for dividing said output  $V_A$  by divisor factor here called  $\eta$ , and

means are provided for subtracting said  $V_A$  divided by said  $\eta$  from said  $V_B$  to form a difference, which is the error corrected difference  $V_C$ , and

also, during said state (A) said gain  $g$  has the value  $g_A$ , and said noise sensitivity  $\Psi$  has the value  $\Psi_A$ ;

and further, during state (B) ; said gain  $g$  has the value  $g_B$ , and said noise sensitivity  $\Psi$  has the value  $\Psi_B$ ;

the ratio of said  $g_B$  divided by said  $g_A$  is called  $G$ , i.e.,

$$G = \frac{g_B}{g_A},$$

and we herein use the symbol  $\beta$  for the ratio of said  $\Psi_B$  to said  $\Psi_A$ , i.e.,

$$\beta = \frac{\Psi_B}{\Psi_A}, \text{ and}$$

for best results we choose or construct said sensor and build said selective modulator conditions  $M_A$  and  $M_B$  so that said sensor has the essential characteristic that said noise sensitivity ratio  $\beta$  is substantially less than said gain ratio  $G$ , i.e.,

$$\beta \ll G;$$

where an example of a practical case is

$$\beta = \frac{1}{2}, \text{ and}$$

$$G = 1.04, \text{ and}$$

where said factor  $\eta$  is the ratio of said  $V_A$  before said division to that after said division, and

wherein said factor  $\eta$  usually has a value close to  $\frac{1}{\beta}$ , i.e.,

$$\eta\beta = 1; \text{ approximately, and}$$

said difference  $V_C$  comprising a reduced but still useful component of said signal but much less of said noise because the said noise in said  $V_B$  was largely canceled by subtracting said  $\frac{1}{\eta}$  part of said noise in said  $V_A$ ,

so said difference  $V_C$  is what is wanted; an output sensitive to said input  $I$  but with said noise  $N$  largely canceled.

#### Claim 9

An implement with a sensor as claimed in claim 8 wherein said sensor is a non-contact current sensor.

#### Claim 10

a method for correcting an error due to an interfering noise  $N$  in the output  $V$  of a sensor for measuring or controlling a physical quantity such as an electric current, temperature, pressure, etc., by the process here called selective modulation, including but not limited to:

said sensor being chosen or manufactured so that it has the essential characteristic defined in the following terms:

said output  $V$  changes in response to a change in a desired signal input  $I$  and has a gain  $g$  which is defined as the ratio of said change in  $V$  divided by said change in  $I$ , i.e.,

$$g \equiv \frac{\delta V}{\delta I},$$

where said  $\delta V$  represents a partial derivative i.e., a small change in said output  $V$  produced by a small change in said  $I$  represented by said  $\delta I$ , it being understood that all other variables are held constant, and also

said output  $V$  also changes when there is a change in said noise  $N$ , i.e., said output  $V$  has a sensitivity to said noise  $N$ , here called  $\Psi$  and defined so that it is referenced to an equivalent of said input  $I$  by said gain  $g$ , i.e.,

$$\Psi \equiv \frac{\delta V / \delta N}{g}$$

and wherein the signal to noise ratio  $SNR$  of said sensor is the inverse of said  $\Psi$ , i.e.,  $SNR \equiv \frac{1}{\Psi}$ ,

and

said sensor is also chosen or manufactured so that it has an operating parameter here called  $Q$ , the condition of which, when altered by selective modulation  $M$ , substantially modifies the value of said signal to noise ratio  $SNR$ , and

said method involves finding or constructing said sensor having said essential characteristic within the bounds of practical values or conditions of said selective modulation  $M$  so that said error correction is useful, an example being;

said  $M$  has values  $M_A = 20$  and  $M_B = 50$

said  $g$  has values  $g_A = 10$  and  $g_B = 11$

said  $\Psi$  has values  $\Psi_A = 35$  and  $\Psi_B = 14$

Then the ratios of said values are:

$$\frac{M_B}{M_A} = \frac{50}{20}, \quad \frac{g_B}{g_A} = \frac{11}{10}, \quad \frac{\Psi_B}{\Psi_A} = \frac{14}{35},$$
$$= 2.5, \quad = 1.1, \quad = 0.4,$$

Said  $\frac{\Psi_B}{\Psi_A} = 0.4$  has been found to be useful and practical, and

the said method also involves combining, usually by subtracting the said output when said selective modulation M has one or more values in a first range, all divided by a divisor factor here called  $\eta$ , from the said output when said M has one or more values in a second range;

where for said error correction the value of said  $\eta$  is usually close to said  $\Psi_A$  divided by said  $\Psi_B$ , as in the above example, but the value of  $\eta$  is adjusted for best said error correction,

$$\eta = \frac{\Psi_A}{\Psi_B}, \text{ approximately,}$$
$$= \frac{35}{14}$$
$$= 2.5; \text{ and}$$

The result of said combining which may be said subtracting is the desired said error corrected output  $V_c$  of said sensor; and

to be effective the result of said combining should be computed during a time when both said signal input and said noise are essentially constant, or so conditioned, or alternatively,

said combining can be done continuously, with practically no limitation on the duration of said time during which said signal and said noise are constant,

when two said sensors, here called sensor A and sensor B, with outputs  $V_A$  and  $V_B$  are used simultaneously with the said operating parameters Q set to operate continuously at different conditions  $M_A$  and  $M_B$  so that said sensor A has said  $SNR_A$ , and said sensor B has said  $SNR_B$ ,

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said combining which may be said  $V_A$  is divided by said  $\eta$ , and said result of said subtracting  $V_C$  is made continuously available as said error corrected output.

Claim 11

A method as claimed in claim 10 wherein said sensor is a non-contact current sensor.

Claim 12

A method and process for constructing and using a sensor with reduced error for measurement or control including means:

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a core of low magnetic reluctance material, here called SQ,

a coupling sense winding on said core having a number of turns, here called  $N_s$ ,

an inverter having an output current, here called  $i_s$ , and an average said output current here called  $I_s$ , and also constructed such that said inverter has an operating parameter which is the peak value in either direction of said current, here called  $I_{sm}$ ,

a low input impedance means converting the said average value  $I_s$  of said inverter current to an output voltage here called  $V_C$ ,

and said method includes:

positioning said core so that it is influenced by a conductor carrying a signal current  $I$  to be measured,

said position being within the effective range of a magnetic field noise, here called  $N$ , causing at least part of an error in the form of a change in zero offset of said output voltage  $V_C$ , wherein

the sensitivity of said  $V_C$  to said noise  $N$  is here called  $\Psi$ , and defined as the change in said  $V_C$  due to a unit change in said noise  $N$  divided by a gain  $g$ , i.e.,



$$\Psi \equiv \frac{\delta V_c / \delta N}{g}, \text{ where}$$

said  $g$  is defined as the change in said output  $V_c$  due to a unit change in said signal current  $I$ ; i.e.,

$$g \equiv \frac{\delta V_c}{\delta I}, \text{ and}$$

said method also includes series connecting said  $N_s$ , said inverter, and said low input impedance means converting;

and adjusting said means, including said  $N_s$  and said  $I_{sm}$ , so that the change in said gain  $g$  is considerably less than the change in said noise sensitivity  $\Psi$ , as said noise sensitivity  $\Psi$  is reduced from a maximum to a value considerably less than said maximum, said reduced being accomplished by altering the value of said means, especially the number of turns on said winding  $N_s$  and the said peak inverter current  $I_{sm}$ , said altering being preferably in the direction of a greater value of the product of said  $N_s$  and said  $I_{sm}$ ,

and operating said sensor with said product of said  $N_s$  and said  $I_{sm}$  set so that said noise sensitivity  $\Psi$  is considerably reduced below said maximum,

thereby constructing and operating said sensor with said reduced error in zero offset due to said noise  $N$ .

#### Claim 13

A Swain Meter type non-contact direct current ammeter with improved accuracy for measurement or control, which comprises:

a core, here called SQ, of low magnetic reluctance material,

a coupling sense winding, here called  $N_s$ , on said core SQ,

an inverter with power supply, here called X, with output terminals with a current  $i_s$  flowing which has an average value  $I_s$ , and also a peak value  $I_{sm}$  which is an operating parameter, all of said currents flowing in either direction in said output terminals,

a low input impedance means converting said average current  $I_s$  to an average output voltage V,

a current carrying conductor carrying a signal input current I, which is to be measured or controlled, positioned so that said current I influences said core SQ, and

said core SQ is within the effective range of an interfering magnetic field noise, here called N, and

said coupling sense winding  $N_s$  series connected with said output terminals of said inverter X and said low input impedance means converting,

said operating parameter  $I_{sm}$  set to a substantially greater magnitude than the magnitude corresponding to the minimum signal to noise ratio, here called SNR, so that thereby the said SNR is considerably increased over said minimum, so that said non-contact ammeter has considerably greater accuracy in the presence of said interfering magnetic field noise N.

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